INTEGRATED WINE QUALITY SENSOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to wine production and inspection methods, and more specifically, it relates to a device and method for evaluating the condition and state of wine while still in the bottle. This device can be easily used to measure specific properties important to the taste and quality of the wine.

Description of Related Art

Archeological clues suggest that grapes were cultivated as far back as 4000 B.C. Stronger glass, tighter stoppers, and Louis Pasteur's research into fermentation in the 19th century allowed the production of wine to develop into the huge commercial industry that it is today. All wine whether still, sparkling, fortified, or aromatized is fermented grape juice. Wine may be red, white, or pink, dry, medium, or sweet in style with an alcohol content of 5.5% to 14%. Grape spirit may be added to fortified wine, raising the alcohol level to 15% to 22%. Sparkling wine contains trapped carbon dioxide (CO_2) bubbles that are released upon opening.

Over 44 different varieties of grapes are used to make the most popular wines, either singly or in combination with one another. This gives rise to an incredible number of possible chemical mixture compositions from one type of wine to another. The chemistry of wine can be complex. Many factors influence the final wine product including the type of grape, age of the grapes, the growing conditions, harvest method and many other factors. As grapes ripen, their acid level usually declines while sugar, color, and tannin levels increase. A wine's need for acidity must be balanced with the desire for richness gained from ripeness. There are numerous exogenous chemicals, which may be added to wines such as, sulfur dioxide (SO_2); a sulfite may be added to control oxidation and kill unwanted bacteria. Additionally, it is important to measure the sulfur dioxide concentration to determine wine age and quality. The color of wine, and content of anthocyanins decreases with increasing free sulfur dioxide content – SO_2. It is also important to monitor phenol content as the wine will take on a bad odor if ethyl phenol >400 μg/1 or vinyl phenols >725 μg/liter are present. Many wines are clarified (fined), using agents such as egg whites, gelatin, isinglass (protein from fish), liquid tannin, charcoal, and certain clays. Sorbic acid may be added to inhibit the growth of yeast and bacteria in sweet wines. Ideally acid, alcohol, fruit and tannins should be balanced. Insufficient acidity makes a wine dull (flat and short); excessive acidity makes the wine sharp and raw tasting. An excess of tannins usually makes a wine bitter, but the right amount of both acidity and tannins produces a wine that is refreshing and that has a flavor that lingers. Spoilage of wine is associated with oxidative mechanisms. Increased 0_2 content greater that 40 mg/liter triggers precipitation of excess tannins. Balance can alter with time. Weight refers to the

alcohol content of the wine and body refers to the mixture of fruitiness and alcohol (the feel of it in the mouth). A "well-bodied" wine is alcoholic and fruity, and white wine is crisp with low alcohol content.

The fermentation process for wine usually takes place in two parts. The first part of fermentation is usually conducted in the presence of air and is aerobic. Fermentation conducted in the absence of air is generally the second portion of the process. Wine can turn to vinegar when vinegar bacteria are allowed access to the wine. Infected equipment, fruit or the vinegar fly (Drosophila) may cause the wine to turn. A fermentation trap or airlock may be employed to protect the ferment. The fermentation trap will let gas pressure escape but admit no air. The fermentation trap can also be used to cut off the air supply and force the yeast to turn to a secondary method of self-reproduction without oxygen, which is appreciably more productive of alcohol. The airlock can also act as an indicator as to when fermentation is finished. During the fermentation process yeast must have sugar, warmth, oxygen and a certain amount of nitrogenous matter, vitamins and some acid. If the recipe does not provide all of these or even if any one of them is lacking, the ferment may stick, or temporarily stop. Some fermentation processes are so specific that yeast are laboratory cultured from the yeasts or grapes from the place of the origin of the wine that is desired to be made.

The process of forming wine in casks or vats is also extremely specific. Occasionally, a third fermentation (Malo-Lactic) occurs. This usually happens a year or more after the wine has been bottled. The optimum pH level for wine is usually 3.2 but may vary between 3.0 to 3.4. The low acidity prevents the production of many

chemical species associated with wine spoilage and the growth of microorganisms. One of the earliest and most sensitive indicators of wine spoilage or impending spoilage is the rise in pH. Increased pH reduces the stability of the anthocyanin pigments and leads to early loss of color. Coupled with spectroscopic analysis of color, pH changes should increase the sensitivity of the measurements for determining aging or spoiling of the wine. Pasteurization is usually implemented to stabilize wine.

The effect of aging wine in the bottle is associated with a color shift from red to brown. Red wines initially deepen in color after fermentation but later take on a lighter ruby then a reddish-brown hue. Decreased color intensity and browning result from a disassociation of anthocyanin complexes (found in young wines) and the progressive formation of anthocyanin-tannin polymers.

The use of new technology has brought about greater control over all stages of wine making, thus reducing production times but also driving up the production costs. The use of stainless steel has become very important to the wine industry in that it allows rigorous temperature control, as well as an inert environment to manipulate the chemistry while preserving the wine's purity. Stainless steel also aids in the strict hygiene requirements of the wine industry. Hygiene is important from a practical standpoint as well as chemically since bacterial contamination may convert the wine to acetic acid and thus vinegar. Although, the exact procedure for bottling wine varies, the bottling usually takes place in a sterile environment and is usually fully automated. Bottling equipment is both complex and expensive since it is important to minimize aeration and agitation. There are several different types of seals that may be placed

over the bottle to prevent oxygen from getting to the wine and reduce spillage. Wine corks are generally made from cork-oak bark that can occasionally become infected with unwanted microorganisms resulting in the wine tasting musty or woody. Plastic and reconstituted corks are an inexpensive alternative and are used mostly on modest wines.

A method and apparatus is needed to accurately and efficiently measure specific properties important to the taste and quality of wine while still in the bottle. International Publication No. WO 93/17324 dated September 2, 1993 provides an apparatus and method for analyzing the alcohol content of beer and wine. This method only monitors the alcohol content and no other chemicals. Also, this method is not concerned with the alcohol content after bottling; rather the monitoring would only take place during the production process.

With technological improvements and the ever increasing popularity of wine, as well as the high prices commanded by certain specialty wines, it would be useful to have an exact measurement of the chemistry of the wine contained within a specific bottle. These measurements could than be compared to the standardized norms and/or authenticated for the purposes of reducing counterfeiting of wines and utilizing the wine before it is beyond its peak of quality. In a commercial, retail or restaurant setting this would prevent sales, delivery or opening and presentation of wines that have become spoiled.

There is a need for a sensor integrated into beverage bottles that can be easily probed to determine the state of the beverage. The present invention fulfills this need, and further provides related advantages.

SUMMARY OF THE INVENTION

It is an object of the present invention is to provide a sensor system and method for measuring the condition of wine while still in the bottle.

In particular, the system can be used to quickly determine the state of wine by measuring a wide variety of wine qualities (e.g., alcohol, sugar, pH, etc.). These measurements can be monitored on a regular basis and used to determine the optimum time to open the bottle and drink the wine. Since individual tastes are different, the user can base the decision on their personal analysis of the measured parameters.

The present invention can be used to measure the quality and state of wine that is still in the bottle. A handheld measuring device is placed on a sensor package that may be integrated into the bottle either on the glass or within the seal. In one embodiment, the sensor is fused or bonded to the glass of the bottle where a hole allows the sensor to contact the wine and take measurements. In order to prevent wine contamination, the sensor element could be coated with a polymer. When the sensor package is integrated into the seal (e.g., cork) of the wine bottle, the sensor element can be placed directly in or within a few millimeters of the wine. The wine diffuses into the cork and the sensor can measure the wine content as well as minimize the risk of contamination. The device measures the chemical make-up of the wine. Values are displayed on the handheld device, allowing the user to determine the condition of the wine.

The sensor elements that comprise the internal side of the sensor package incorporate fiber optics and electrochemical sensors to allow a wide variety of measurements. Measurement of scattered light can be used to determine the presence of solid material in the wine. Additional wine properties (e.g., pH, alcohol, dissolved oxygen) are measured by electrochemical or optical chemical sensors placed between the fibers.

A hinged cover can be used on the sensor package to protect the fiber optic and electrical connectors on the package. A sensor number can be included on the inside of the cover and can be input into the measuring device to be used to accurately interpret the measurements. The handheld measuring device and the sensor package will only operate when the electrical and optical connections are properly aligned. This configuration is possible for the sensor package whether the sensor package is fused to the bottle or integrated into the cork.

The handheld measuring device is comprised of a housing that fits around the sensor package to insure proper contact during the measuring process. The device is battery powered and includes a microprocessor and LCD display. Alternate displays may be used, e.g., an OLED. When activated, the microprocessor reads the digitized signal from all of the sensors and displays the data on the electronic display. Also contained within the device is a broad wavelength light source that transmits light down an optical fiber into the sensor package and transmits through the wine and back into the optical detector. Sensor electronics power the electrochemical sensors. The number of sensors used would be determined by the size and cost of the device. In

order to avoid wine contamination it would be necessary to consider the type of sensors employed.

In one embodiment of the invention, all the sensor data measured by the device can be downloaded into a computer where it can be stored for future comparison. The computer can also be used to download information from the winery about interpretation of the sensor readings for each individual wine type. In order to improve interpretation of sensor data and eliminate effects of sensor drift, each winery can maintain a group of control bottles. Each year a bottle is first measured using the present invention and then opened to measure all properties accurately using proven laboratory techniques. The results are used to post information on the Internet that can be downloaded by consumers to calibrate their own measurements. With time, the consumer will also develop a library of what sensor readings are optimum for their particular tastes.

Although this disclosure describes in detail the use of this invention for wine, a similar system could be used for other alcoholic beverages.

These and other objects will be apparent to those skilled in the art based on the teachings herein. Other objects and advantages of the present invention will become apparent from the following description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form part of this disclosure, illustrate embodiments of the invention and together with the description, serve to explain the principles of the invention.

Figure 1 shows a way the device may be used to measure the state of wine within a bottle.

Figure 2 shows a sectional view of an embodiment of the wine sensor, as it could be integrated into a bottle.

Figure 3 shows a sectional view of the wine sensor, as it would be integrated into the cork of a wine bottle.

Figure 4 shows a view of the internal side of a sensor package.

Figure 5 shows a view of the external side of a sensor package.

Figure 6 is a schematic illustration of an embodiment of the handheld measuring device.

Figure 6 shows the absorption spectra of three red wines of different ages.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates how an embodiment of the present invention can be used to measure the state of wine in a bottle. The measuring device **10** is placed on the sensor package **20**, which is integrated into the bottle **30**. The user would then use the values read from display **12** on the measuring device **10** to determine the condition of the wine.

Figure 2 shows a cross sectional view through the sensor package **20** and the bottle **30**. The sensor package **20** is fused or bonded to the glass of the bottle where a hole allows the sensor elements **40** to contact the wine. The sensor elements can be coated with a polymer to reduce any risk of wine contamination.

Figure 3 show how the sensor package **20** can be integrated into the cork **50** of the wine bottle **30**. In this embodiment, the sensor elements **40** can be directly in contact with the wine or be within a few millimeters of the end of the cork. Since wine diffuses into the cork, sensors within a few millimeters of the end of the cork can sample the wine and minimize the risk of wine contamination. In another embodiment, the sensor package **20** is placed in the region between the cork and the bottle.

Figure 4 shows a view of one embodiment of the sensor elements **40** that forms part of the internal side of the sensor package **20**. This embodiment incorporates fiber optics and electrochemical sensors to allow a wide variety of measurements. Light transmitted into the input fiber **100** by the measuring device **10 (Figure 1)** is reflected by a corner cube **120** that directs the light through another corner cube **140** into a secondary fiber **150**. In the bottle, wine fills the gap between the two corner cubes allowing the absorption spectrum of the wine to be measured by the measuring device **10 (Figure 1)**. In order to improve light coupling between the two fibers, GRIN or other miniature lenses can be added to each fiber optic. An additional fiber **160** collects scattered light off corner cube **170**. The measurement of scattered light can be used to determine the presence of solid material in the wine. Instead of using corner

cubes (**120, 140, 170**) to redirect the light, it would also be possible to bend the optical fibers. This would require the fiber optic to extend further into the bottle to prevent excessive loss of light through the sharp bend.

Electrochemical sensors **180** or optical chemical sensors **190** placed between the fibers are used to measure additional wine properties (e.g., pH, alcohol, dissolved oxygen). Liquid phase chemical sensors generally use enzymatic layers that are extremely selective to a given substrate and highly effective in increasing the rate of reactions. The enzyme is generally immobilized inside a layer into which the substrate diffuses. A wide variety of liquid phase chemical sensors currently exist which can be employed in the present invention (See e.g., "Handbook of Modern Sensors", by Jacob Fraden 1996, and "Handbook of BioSensors and Electronic Noses Medicine, Food and the Environment", ed Erika Kress-Rogers, 1996, incorporated herein by reference). Electrochemical sensors produce a voltage or current that is proportional to a measured quantity. Optical sensors use changes in absorption or fluorescence to measure molecular concentration or fluid property.

Figure 5 shows a view of the external side of one embodiment of the sensor package **20**. This embodiment includes a hinged cover **200** that protects the fiber optic **210** and electrical connectors **220** on the package. Rather than a hinged cover a simple cap can be used. In addition, the inside of the cover contains a sensor number **230** that can be input into the measuring device and used to accurately interpret the measurements. Electrical and optical connection between the measuring device and the sensor package is only possible when the device is properly aligned. In **Figure 5**, the

sensor package is shown bonded to the bottle **30**, a similar configuration is possible for a sensor package integrated into the cork of the bottle.

Figure 6 shows a schematic illustration of an embodiment of the handheld measuring device **10**. The device comprises a housing **300** that fits around the sensor package to insure proper contact for the duration of the measurement. The fiber optic **310** and electrical connection pins **315** protrude beyond the base plate **320** to dock with the sensor elements on the sensor package. Within the battery powered measuring device, software controls the operation of a microprocessor **330**. The microprocessor receives inputs from the user through buttons **340**, and displays menus and results on a LCD display **350** (shown as element **12** in **Figure 1**). When activated, the microprocessor **330** reads the digitized signal from all sensors. The microprocessor **330** can include an integrated analog to digital converter or require a separate analog to digital converter IC. The collected readings are analyzed by the software and displayed on the LCD display **350**. In addition, for single property measurements, the measured absorption spectrum can also be displayed on the LCD display **350** as a graph.

A broad wavelength light source **360** within the device transmits light down an optical fiber **365** that goes into the sensor package and is transmitted through the wine and collected back into optical detector **370**. Optical detector **370** can be a linear CCD coupled to a grating spectrometer to enable the fluorescence and/or absorption spectrum of the wine to be measured over a wavelength region extending from 300-1300 nm. Optical detector **370** could also be a set of individual filtered optical diodes

that would measure the fluorescence and/or absorption characteristics at a few discreet wavelengths. The standard method of measurement is to calculate a ratio of optical density measurements at 520 nm and 420 nm. A review of the characteristic changes in the overall spectrum suggests that a scan from 350 to 600 nm contain information relative to the aging of the wine (**Figure 7**). Another optical detector within the device measures the light collected by fiber **170** (**Figure 4**).

An excitation light source **380** couples light into a fiber optic splitter **385** that sends light down to the optional fiber optic chemical sensors **190** (**Figure 4**). The resulting fluorescence signal returns from the sensor package and is detected by an optical detector **390**. Sensor electronics **400** power the electrochemical sensors **180** (**Figure 4**) and condition the signal for the analog to digital converter. The number of sensors is only constrained by the size and target cost of the device. In addition, the type of sensor is constrained by the requirement that little or no contamination of the wine occurs.

In the preferred embodiment all the sensor data measured by the device can be downloaded into a computer where it can be stored for future comparison. The computer can also be used to download information from the winery about interpretation of the sensor readings for each individual wine type. In order to improve interpretation of sensor data and eliminate effects of sensor drift, each winery can maintain a group of control bottles. Each year a bottle is first measured using the present invention and then opened to measure all properties accurately using proven laboratory techniques. The results are used to post information on the Internet that can

be downloaded by consumers to calibrate their own measurements. With time the consumer will also develop a library of what sensor readings are optimum for their particular tastes.

Examples of the types of data, indicative of wine quality, that may be sensed by the present invention include galacturonic acid, gums – polysaccharides of arabinose and galactose; tartaric acid, malic acid, citric acid, succinic acid, lactic acid, acetic acid, potassium bitartrate, formic , Yair Margalit, Pacid, oxalic acid, pyruvic acid, butyric acid, iso-butyric acid, hexanoic acid, octanoic acid, a-Ketoglutaric acid, ethanol, methanol, methyl ester, n-propanol, isopropanol, n-butanol, isobutanol, n-amyl alcohol, 3-methylbutanol, 2-methylbutanol, n-hexanol, 2-phenylethanol, polyalcohols (polyols), 2,3-butandiol, glycerol, eythritol, xylitol, arabitol (also called arabinitol), mannitol, acetaldehyde, acetoin and diacetyl, acetate, butyrate, oxanoate and other esters, ethyl acetate, ethyl formate, propyl acetate, isopropyl acetate, isobutyl acetate, isoamyl acetate, phenylethyl acetate, ethyl propionate, ethyl valerate, ethyl hexanoate (caproate), ethyl octanoate (caprylate), ethyl decanoate (caprate), ethyl lactate, ethyl succinate (acidic ester), methyl o-anthranilate, amino acids, diammonium phosphate, proteins, nitrates, amino acid esters, vitamins, biotin, choline, gallic acid, coutaric acid, caftaric acid, fertaric acid, catechin, epicatechin, gallocatechin gallate, procyanidin (B1, B2, B3), catechin catechin gallate, hydroxycinnamic acid esters (coutaric, caftaric, fertaric), acids, glutathionyl caftaric acid, catechin+epicatechin, catechin-gallate, afzelechin, catechin, epicatechin, and gallocatechin, flavane (3,4) diol, flavonol-3, cyanindin, delphinidin, peonidin, petunidin, mallvidin, anthocyanins, glycosic, catechin, epicatechin, potassium, sodium, calcium, iron, lithium, magnesium, copper,

lead, manganese, aluminum, zinc, rubidium, arsenic, nickel, anions, phosphate, sulfate, borates, silicates, halogens, fatty acids, boron, florine, silicon, phosphate, sulfate, chlorine, bromine, iodine, anions, sulfur dioxide, acetaldehyde-bisulfite (bound SO_2), fumaric acid, vinylbenzene, benzaldehyde, γ-nonalactone, ethyl phenylacetate, p-hydroxybenzoic acid, p-pyrocatechuic acid, gallic acid, vanillic acid,syringic acid, salicyclic acid, o-pyrocatechuic acid, gentisic acid, cinnamic acid, cinnamic acid, p-coumaric acid, caffeic acid, ferulic acid, sinaptic acid, coutaric acid, caftaric acid, fertaric acid, digallic acid, ellagic acid, flavonoids, afzelechin, catechin, gallocatechin, glycosides, tannins, flavylium ion, anthocyanins, pelargonidin, cyanidin, delphinidin, peonidin, petunidin, mallvidin, ethyl acetate, ethyl caproate, terpenoids, glycosides, pyrazines, phenolics, chlorogenic acid, methyl anthranilate, ethyl anthranilate, methyl salicylate, ethyl salicylate, 2-methoxymethyl benzoate, 2 methoxyethyl benzoate, ethyl trans-2 –butenoate, ethyl trans-2-hexenoate, ethyl trans-2-octenoate, ethyl trans-2-decenoate, ethyl trans, trans-2,4 decadienoate, ethyl trans, cis-2,4 decadienoate, ethyl trans, trans, cis-2,4,7-decatrienoate, ethyl trans, cis-2,6-dodecadienoate, methyl 3-hydroxybutanoate, dehyl 3-hydroxybutanoate, ethyl 3-hydroxyhexanoate, damascenone, furaneol, methoxyfuraneol, ethyl 3-mercaptopropanoate, trans-2-hexen-1-ol, hydrogen disulfide, carbon disulfide, dimethyl disulfide, dimethyl sulfide, diethyl sulfide, diethyl disulfide, methanethiol, ethanethiol, dimethyl sulfoxide, methyl thiolacetate, ethyl thiolacetate, cis and trans-2-methylthiophan-3-ol, 5-[hydroxyethyl]-4-methylthiazole, thio aliphatic alcohols, methanionol, or 3-(methylthio)-propanol, polyphenoloxidases, laccase, chlorogenic acid, protocatechuic acid, glutathione,, 2-S-

glutathionylcaftaric acid, acetaldehyde, 13C-Norisoprenoids,1,1,6-trimethyl-1,2-dihydronaphthalene (TDN), vitispirane, ellagic acid, lignins, gallic acid, aromatic aldehydes, vanillin, syringaldehyde, coniferyaldehyde, sinapaldehyde, γlactones, cis-β-methyl-γ-lactone, trans-β-methyl-γ-lactone, maltol, cyclotene, ethoxylactone, furfural, furfuryl alcohol, Guaiacol, geosmin, anthocyanine-bisulfite, malvidin glucoside, quinones, tartaric acid, potassium bitartrate, calcium tartrate, furmaric acid, calcium carbonate, sorbic acid, ethyl sorbate, benzoic acid and sodium benzoate, diethyl dicarbonate (DEDC), dimethyl dicarbonate (DMDC), iron, copper, aluminum, hydrogen sulfide, mercaptan, diethyl sulfide, ethyl mercaptan, (1)pH, diacetyl, acetoin, 2,3-butandiol, 2-ethoxyhexa-3.5-diene, histamine, tyramine, putrescine, cadaverine, ethyl carbamate, urea and carbamyl phosphate.

The wide use of cork as wine stopper started only at the middle of the 17th century. It is related (truly or not) to a monk named Dom Perignon who looked for a solution to secure his sparkling wine in a closed container. Since then the innovation of cork became one of the most important contributions to the development of the wine industry. The production of cork stoppers is a long process. Boiling eliminates insects and other living objects from the bark, and it also removes polyphenols and other volatile substances. The bars are cut into strips, washed and bleached. After grading, the corks undergo surface treatment with various food grade coating materials (paraffin, silicon oil, wax). The object of surface coating is to ease the insertion of the cork into the bottle, and also to ease the later extraction when the bottle is opened. The corks are then sealed in plastic bags containing SO_2 gas to ensure some sterility on

shipment. The phenomenon of corktaint or "corkiness" is characterized by a moldy/musky/smoky off-flavor. The components found in corks which might be responsible for corktaint are: 2,4,6-Trichloroanisole, o-Hydroxyanisole,1-octen-3-one and 1-octen-3-ol,Trans-1,10-dimethyl-trans-9-decalol, 2-methylisoborneol and TCA (trichloroacetic acid). The present invention is usable for measurement of these and other components indicative of the state or quality of a cork while it is still in the bottle. Figure 3 provides one example of an embodiment that is readily adaptable to this use. Examples of the variety of materials that may be used for the seal include cork, plastics (polymerized urethanes, vinyls, styrenes, etc.), rubbers, resins, waxes, cellulose, cellulose derivatives, synthetic organic compounds (such as nylon), silicones, silicone derivatives, epoxies and glues.

The above descriptions and illustrations are only by way of example and are not to be taken as limiting the invention in any manner. One skilled in the art can substitute known equivalents for the structures and means described. The full scope and definition of the invention, therefore, is set forth in the following claims.